SPECIFICATION

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METHOD FOR CONTRAST MATCHING OF MULTIPLE IMAGES OF THE SAME OBJECT OR SCENE TO A COMMON REFERENCE IMAGE

Background of Invention

[0001] The present invention relates generally to image systems and, more particularly, to matching the contrast of multiple images from the image system.

[0002] Many types of digital imaging systems are known. In the medical field, such systems may include CT systems, X-ray system and MRI systems. In each case multiple digital images may be formed of the same scene or object. The multiple images may be generated using the same input with different parameter sets. In many circumstances there exists a need to evaluate which of these images are optimal so that the appropriate parameters can be obtained. However, the problem with such images is that the brightness and contrast are different. Thus, the images have to be mentally normalized. That is, brightness and contrast differences must be overlooked by the evaluator. This kind of normalization may lead to subjective bias and takes the mind of the evaluator away from the parameter evaluation.

[0003] Image processing algorithms are available in which different parameter choices produce different looks. For example, one set of parameters yields improved smoothness but produces artificially bright undesirable regions. The other set of parameters produces noisy images but without bright regions. Adjusting each image individually is time consuming and may yield inconsistent results.

[0004] It would be desirable to match the brightness and contrast of various types of images such as smooth images and noise images to produce resultant images that are smooth but not artificially bright in one region. Also, there exists a need to match images of the same scene taken at multiple time points such that they can be displayed with the same

brightness and contrast.

Summary of Invention

[0005] The present invention provides image processing that may be used with various types of imaging systems to reduce variability in brightness and contrast between different images.

[0006] In one aspect of the invention, a method of contrast matching a first image and a second image comprising:generating an image ratio of the first image and the second image;regularizing an image ratio of the second image with respect to the first image to form a regularized image ratio;filtering the image ratio to form a filtered ratio; andmultiplying the second image by the filtered ratio to form an adjusted image.

[0007] In a further aspect of the invention, an imaging system includes an image forming device for generating a first image and a second image and a controller coupled to the image forming device. The controller receives the first image and the second image. The controller generates an image ratio of the first image and the second image, regularizes the image ratio of the second image with respect to the first image to form a regularized image ratio and filters the image ratio to form a filtered ratio. The controller then multiplies the second image by the filtered ratio to form an adjusted image.

[0008] One advantage of the invention is that the subjective nature of viewing images having different contrast and brightness portions is reduced. Another advantage is that the process can be automated so that once a first or reference image is chosen a number of images can be matched to the reference image quickly.

[0009] Other aspects and advantages of the present invention will become apparent upon the following detailed description and appended claims, and upon reference to the accompanying drawings.

Brief Description of Drawings

[0010] FIGURE 1 is a schematic illustration of an image system in accordance with a preferred embodiment of the present invention.

[0011] FIGURE 2 is a flow chart for image processing according to the present invention.

Detailed Description

[0012] While the following description is provided with respect to an X-ray device, the present

application may be used with various types of imaging systems including both medical and non-medical related fields. In the medical field, the present invention may be incorporated into but not limited to a CT system, an MRI system system, and an ultrasound system.

[0013] Referring to Figure 1, an imaging system 10 in accordance with the present invention is shown. The imaging system 10 preferably includes a housing 12 containing an x-ray source 14 or other type of image generating source. The housing 12 may be a gantry having the ability for movement in multiple directions. The x-ray source 14 projects a beam of x-rays 16 towards a detection array 18, which may also be contained within the housing 12. Positioned in between the x-ray source 14 and the detection array 18 is a table 22, preferably not within housing 12, for holding an object 24 to be imaged by the imaging system 10. A data acquisition system (DAS) 26 registers signals from the detection array 18 and sends the information to a computer controller 28 for image processing. Controller 28 is preferably a microprocessor-based personal computer. A control mechanism 29 may be used to control the movement and position of the system components as well as power and timing signals to the x-ray source 14.

[0014] The imaging system 10 may also include a monitor 30 and storage medium 32 for viewing and storing information. While electronic and control mechanism are illustrated, they are not required to perform the imaging techniques described herein and are merely being shown for illustration purposes only.

[0015] Although such a system describes generically an imaging system, the present invention preferably utilizes a high-resolution imager. The imager has a pixel location and dimension of a high order of magnitude precision. Thus, each image will have multiple pixels in the image that will be covered by the shadow of the object. These multiple pixels can then be mathematically evaluated to calculate either a size or position that has a degree of precision that is a small fraction of the dimension of any one pixel. High-resolution imagers are well known in the prior art.

[0016] The detection array 18, on such high-resolution systems, includes a plurality of pixel panels 19, although a variety of pixel panel 19 shapes, sizes and densities are contemplated. In addition, it is required that variations in pixel size and location be minimized. A variety of detection arrays 18 includes a glass substrate 34, a photodetector array 36 and a scintillator 38. In other embodiments, however, alternative detection array 18 configurations are contemplated.

[0017] Referring now to Figure 2, the imaging processing is described. In step 50, images that are desired to be imaged matched are stored into the system. This may be done at one time or over a period of time. As mentioned above, this may be performed using various types of imaging devices. The process described below pertains to two images. The same process may be used for multiple images in a similar manner as will be described below.

[0018] In this example, two images $A1$ and $A2$ of the same object or scene are to be imaged matched A2 to A1. For every pixel of $A1$ and $A2$, the following relation holds: $A1 = A2 * (A1/A2)$. By differentiation of the logarithm of the above equation, the contrast function $C(.)$ at a given location is denoted by : $C(A1) = C(A2) + C(A1/A2)$. As will be further described below, the image division A1/A2 may optionally be regularized relative to the image to be matched A1 in step 52 when the image quality is not good, e.g., noisy. Various types of regularization may be performed. Regularization will be further described below.

[0019] In order to satisfy $C(A1) = C(A2)$ in the above equation, $C(A1/A2) = 0$. A well known way to decrease the contrast is to low pass filter the ratio $A1/A2$ is shown in step 54. Therefore in step 56, contrast matching output equation for the two images A1 and A2 is thus: $A1_{M2} = A2 * LPF(A1/A2)$, where $A1_{M2}$ is the contrast matched version of $A2$ with respect to $A1$ and $LPF(.)$ is a low pass filter function. The low pass filter function is further described below.

[0020] For multiple (N) images, let $A1, A2, ., AK.., AN$ be the N images under consideration ($K < N$) and each of these images are to be matched to the same reference image A1. By extending the above logic to any of N images, say image K, the general relationship exists: $A1_{MK} = AK * LPF(A1/AK)$, where $A1_{MK}$ is the contrast matched version of AK with respect to $A1$. Thus, a generalized contrast matching has been achieved since, $C(A1) = C(A1_{M2}) = \ldots = C(A1_{MK}) = \ldots = C(A1_{MN})$.

[0021] The choice of parameters in the low pass filter function essentially determines the scale of contrast matching obtained. Various types of low pass filters may be used. For example, a boxcar filter with a single parameter may be used. A boxcar filter smoothes an image by the average of a given neighborhood of pixels. It is separable and efficient methods exist for its computation. Each point in the image requires just four arithmetic operations, irrespective of the kernel size. The length of the separable kernel is variable and depends on the scale of contrast matching desired. For example, if the kernel size is about one tenth of the image size, assuming a square image and a square kernel, excellent global contrast matching of

images is obtained. On the other hand, using too small a kernel size produces undesirable blobby patterns in the matched images. Therefore, a reasonably large kernel should be used to avoid any perceptible artifacts using this method.

[0022] To summarize, an image *A2* has to be matched to another image *A1* of the same scene/objects to obtain the matched image $A1_{M2}$ using the relation: $A1_{M2} = A2 * LPF(A1/A2)$, where LPF is a low pass filter function. Preferably the low pass filter function is a boxcar filter and the parameters of the filter are application specific. For general applications, the filter kernel length is one-tenth the length of the image (assuming a square image and square kernel). Furthermore, in practice, the above equation may need to be modified in order to avoid noise amplification during image division. Regularization may be performed in a number of methods to prevent noise amplification during image division. The image division ratio has a numerator A1 and a denominator A2. One method to regularize image division is to add a small constant to the denominator, i.e., denominator becomes $(A2 + \epsilon)$ where as an example, $\epsilon = 1.0$. Thus the equation becomes: $A1_{M2} = A2 * LPF(A1/(A2+\epsilon))$.

[0023] Of course, if no regularization is to be performed, ϵ would be 0.

[0024] Another method for regularization is to replace the ratio (A1/A2) by a regularized ratio given by $(A1 * A2/(A2 * A2 + \delta))$, where as an example, $\delta = 1.0$. Thus the equation becomes: $A1_{M2} = A2 * LPF(A1 * A2/(A2 * A2 + \delta))$.

[0025] When a number of images *A2, ... , AK, ... , AN* have to be matched to a single image *A1*, the above process may be performed in a pair wise fashion to obtain $A1_{M2}, \ldots, A1_{MK}, \ldots, A1_{MN}$.

[0026] While the invention has been described in connection with one or more embodiments, it should be understood that the invention is not limited to those embodiments. On the contrary, the invention is intended to cover all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the appended claims.